Chapter 4
ROADS

An adequate road network is needed to transport troops, equipment, and supplies in support of the combined arms team in the Theater of Operations. Depending upon the mission, situation, and terrain, the road system usually carries most of these assets. Responsibility for road construction and maintenance within the theater rests almost wholly with the Army. While no engineer unit is designed solely for road construction and maintenance, many engineer elements in the theater are actively engaged in this task.

ROAD NET REQUIREMENTS

TYPES OF ROADS

Roads in the Theater of Operations are classified according to their location, trafficability, and degree of permanence. Military roads are rarely constructed to meet the exacting requirements of civilian construction. Standards vary—combat trails and roads in the Forward Combat Zone (FCZ) (FM 5-101) may be hastily-cut pathways designed only to enhance mobility for a short time. More permanent networks—Main Supply Routes (MSRs) and Lines of Communication (LOCs)—are designed and built to higher standards. This manual addresses more permanent road construction and maintenance.

Sound engineering logic and the urgencies of the military situation dictate that existing roads be used whenever possible. Exceptions include the construction of roads in support of United States Marine Corps (USMC) amphibious operations and road maintenance on installations or bases of other services. Where suitable networks do not exist, roads are upgraded or constructed to the following specifications.

Temporary roads

Temporary roads are designed with a life span of up to 2 years. Frost design is omitted. Roads within the Theater of Operations are nearly all constructed to temporary standards.

Permanent roads

Permanent roads are designed for greater than 2 but less than 20 years of use. Frost design is incorporated.

Subclassification

Within temporary and permanent specifications, roads are subclassified as type A, B, or C according to the amount of traffic planned per day. Type A roads are designed for the highest capacity, while type C roads are planned for the lowest.

CONSTRUCTION RESPONSIBILITIES

Engineer elements, under the appropriate Army command, have the following responsibilities:

- Road and bridge reconnaissance.
- Recommendations for traffic circulation as it pertains to terrain and construction considerations.
- Maintenance, repair, improvement, and construction of roads and bridges.
- Topographic support (FM 5-105).

ROAD PLANNING

The following factors must be considered in all Theater of Operations road planning design:

Location

Route location is dictated by military necessity. Where possible, however, use existing roads to avoid unnecessary construction.

Simplicity

Use simple designs that require a minimum of skilled labor and specialized equipment. Use available materials.

Economy of time

Speed is critical to road construction in the Theater of Operations. The nearer the required road is to the forward area, the more vital it becomes. Save valuable time—use manpower, equipment, materials, and facilities efficiently.

Economy of materials

Conserve materials, especially those shipped from outside the Theater of Operations. Use local materials wherever possible.

Planning and management

Use effective job management. Good planning, careful scheduling, and thorough supervision speed job completion and save time, labor, equipment, and materials. Wherever possible, use staged construction to allow the early use of roadways while further construction and improvement continue.

Terrain

Study slopes, drainage, vegetation, character of soil, likelihood of floods, and other conditions that may affect construction and layout. Avoid dense brush, timberland, and rolling terrain that require heavy clearing or grading.

EXISTING ROUTES

RECONNAISSANCE

Conduct route reconnaissance to evaluate the traffic-bearing capabilities of previously-constructed roads. Results support route selection decisions designed to facilitate unit and logistical movement within the theater. Reconnaissance also determines improvements needed before a route can carry proposed traffic.

Types

Route reconnaissance is classified as either hasty or deliberate. Hasty route reconnaissance determines the immediate military trafficability of a specified route. It is limited to critical terrain data necessary for route classification. The results are presented as an overlay supplemented by such additional reports as are required by the situation and the commander's guidance. A deliberate route reconnaissance is conducted when sufficient time and qualified personnel are available. Deliberate route reconnaissance is usually conducted when the situation demands protracted use of an MSR. An overlay is made with enclosures that describe all pertinent terrain features in detail. These documents form a permanent record which is retained at the engineer unit tasked to perform the reconnaissance. Pertinent information is forwarded to the corps and theater transportation offices to be used in transportation planning. The data may also be used to manufacture special overprinted route maps with the assistance of engineer topographic units.

Information sought

The engineer reconnaissance team is briefed as to the anticipated traffic (wheeled, tracked, or a combination) and the anticipated traffic flow. Single flow traffic allows a column of vehicles to proceed while individual oncoming or overtaking vehicles pass at predetermined points. Double flow traffic allows two columns of vehicles to proceed simultaneously in the same or in opposite directions (see FM 5-36). The reconnaissance team may also be asked to determine the road name or designation, the location of the road by map grid reference, and the nature and location of obstructions.

Obstructions are defined as anything that reduces the road classification below that required to handle proposed traffic efficiently. Obstructions include—

- Restricted lateral clearance, including traveled way width such as bridges, built-up areas, rock falls or slide areas, tunnels, and wooded areas.
- Restricted overhead clearance, including overpasses, bridges, tunnels, wooded areas, built-up areas.
- Sharp curves.
- Excessive gradients.
- Poor drainage.

- Snow blockage.
- Unstable foundation.
- Rough surface conditions.
- Reinforcing obstacles, including NBC contamination, road blocks, craters, and minefield.

Existing bridging may require special attention, as it is often a weak link. It may be necessary to conduct a bridge reconnaissance and classification computations (see Chapter 5 of this manual).

UPGRADING EXISTING ROADS

Upgrading an existing road, combined with routine maintenance and repair, usually involves reducing or eliminating obstructions listed above. It is the preferred method of improving the trafficability of a selected route. Techniques, equipment, and materials needed for upgrading are the same as those required for new road construction.

A changing tactical situation and unpredictable military operations may also require that engineer troops modify and expand completed construction. The location of a road should allow for potential expansion. Expanding an existing route or facility conserves manpower and material and permits speedier completion of a usable roadway.

MAINTENANCE AND REPAIR

Road maintenance is the routine prevention and correction of damage and deterioration caused by normal use and exposure to the elements. Repair restores damage caused by abnormal use, accidents, hostile forces, and severe environmental actions. Rehabilitation restores roads that have not been in the hands of friendly forces and do not meet theater requirements.

ROUTINE MAINTENANCE AND REPAIR

Routine maintenance and repair operations include inspection and supervision, stockpiling materials for maintenance and repair work, maintenance and repair of road surfaces and drainage systems, dust and mud control, and snow and ice removal. The main purpose of maintenance and repair work is to keep road surfaces in usable and safe condition. It also increases route capacity and reduces vehicle maintenance requirements. Effective maintenance begins with a command-wide emphasis stressing good driving practices to reduce unnecessary damage. Once damage has occurred, prompt repair is vital. After deterioration or destruction of the road surface begins, rapid degeneration may follow. A minor maintenance job postponed becomes a major repair effort involving reconstruction of the subgrade, base course, and roadway surface. The following principles should be observed in conducting sound road maintenance and repair.

Minimize interference with traffic

In order to keep surfaces usable, maintenance and repair activities should interfere as little as possible with the normal flow of traffic. A temporary bypass may be required.

Correct basic cause of surface failure

Effort spent to make surface repairs on a defective subgrade are wasted. Any maintenance or repair job should include an investigation to find the cause of the damage or deterioration. That cause must be remedied before the repair is made. To ignore the cause of the damage is to invite prompt reappearance of the damage.

Reconstruct uniform surface

Maintenance and repair of existing surfaces should conform as closely as possible to the original construction in strength and texture. Simplify maintenance by retaining uniformity. Spot strengthening often creates differences in wear and traffic impact which are harmful to the adjoining surfaces.

Assign priorities

Priority in making repairs depends on the tactical requirements, the traffic volume, and the hazards that would result from complete failure of the facility.

MAINTENANCE INSPECTIONS

The purpose of maintenance inspections is to detect early evidence of defects before actual failure occurs. Frequent inspections and effective follow-up procedures prevent minor defects from becoming serious and causing major repair jobs. Special vigilance must be exercised during rainy seasons and spring thaws, and after every heavy storm.

MAINTENANCE AND REPAIR MATERIALS

The materials required in road maintenance and repair are the same as those used in new construction. Maintenance groups must open pits and build stockpiles of sand and gravel, base materials, and premixed cold patching material. Place materials in convenient locations and in sufficient quantities for emergency maintenance and repair. Arrange stockpiles for quick loading and transportation to key routes.

MAINTENANCE AND REPAIR ORGANIZATION

In forward areas, extensive repairs are often needed to make roads usable. Advance engineer combat units usually do this work. Under the pressure of combat conditions, repairs are sometimes temporary and hurriedly made with the most readily available materials. Such repairs are intended only to meet immediate minimum needs. As advance units move forward, other engineer units take over additional repair and maintenance. Early expedient repairs are supplemented or replaced by more permanent work. Surfaces are brought to a standard that will withstand the required use. Maintenance becomes a matter of routine.

Engineer units establish a patrol system to cover the road net for which the unit is responsible. It is desirable to retain unit integrity by using squads as patrols. Each squad is commanded by its squad leader and uses its organic hand tools and equipment. The squad is augmented with equipment from the company equipment section or battalion equipment platoon. Each patrol is assigned to a specific area. As many patrols as needed are organized to cover the total area of responsibility. The traffic level and the limited durability of a road sometimes make it necessary to put the maintenance function on a 24-hour-a-day basis in forward or heavy traffic areas. A squad-sized patrol equipped with a dump truck, motor grader, and hand tools can usually carry out all maintenance and minor repairs normally encountered on a 5- to 15-mile stretch of road. Squad size can be increased or decreased, and more or fewer miles can be assigned to a patrol as the situation dictates.

WINTER MAINTENANCE

In the Theater of Operations, winter weather may present special maintenance problems. Regions of heavy snowfall require special equipment and material to keep pavements and other traffic areas open. Low temperatures cause icing on pavements and frost effects on subgrade structures. Alternate freezing and thawing may cause damage to surfaces and block drainage systems with ice. Spring thaws may cause both surface and subgrade failures and may damage bridging. Winter maintenance consists chiefly of removing snow and ice, sanding icy surfaces, erecting and maintaining snow fences, and keeping drainage systems free from obstruction. Each command should publish a comprehensive snow- and ice-control plan that clearly specifies the responsibilities of engineer and nonengineer units. Engineer and nonengineer patrols must be established to monitor snow and ice conditions within the area of operations. Available snow- and ice-control equipment and supplies must be allocated to support the plan.

NEW ROAD CONSTRUCTION

ROUTE RECONNAISSANCE

Engineer reconnaissance efforts can be classified by their extent or their comprehensiveness. In extent, reconnaissance may be classified as either area or specific reconnaissance. Area reconnaissance is a search conducted over a wide area to find a general site suitable for construction. Specific reconnaissance is investigation of a particular site or an undeveloped but potential route.

New route reconnaissance may be classified either as hasty or deliberate. The way in which reconnaissances are performed depends upon the amount of detail required, the time available, the terrain problems encountered, and the tactical situation.

Reconnaissance involves the following steps.

Planning

Planning includes coordination of reconnaissance effort by appropriate headquarters, prediction of needs, and assignment of a definite reconnaissance mission.

Briefing

In a briefing, the reconnaissance party is told what site or area to reconnoiter, what is already known, and what information the party is expected to obtain. Pertinent details concerning the times or methods of reporting results are included in the briefing.

Preliminary study

The initial job of the reconnaissance party is to conduct this study. The party reviews information obtained during the briefing, conducts a map reconnaissance of the site or area, studies air photos, delineates soil boundaries, assembles any other available information, and plans and prepares for the actual reconnaissance.

The reconnaissance team may request the following sources of information in planning reconnaissance missions and in making the preliminary study of a specific mission:

- Existing intelligence dossiers; Army and Air Force periodic intelligence reports.
- Strategic and technical reports, studies, and summaries.
- Road, topographic, soil, vegetation, and geologic maps.
- Existing aerial reconnaissance reports; air photos.

Air reconnaissance

An air reconnaissance includes a general study of the topography, drainage pattern, and vegetation. Construction problems, camouflage possibilities, and access routes should be identified. Usually, specific ground reconnaissance procedure is planned by selecting, from the air, the areas to investigate and the questions to be answered. Air reconnaissance can be used to eliminate unsuitable sites, but cannot be relied on for site selection. Aerial photography greatly enhances the usefulness of this method of reconnaissance.

Ground reconnaissance

While air reconnaissance can effectively minimize needed ground reconnaissance, it cannot replace ground reconnaissance. It is on the ground that most questions are answered, or that most observations tentatively made from the air are verified. Often, ground and air reconnaissance are not as distinct as they would seem from this discussion. A continuing air reconnaissance may be interspersed with specific ground reconnaissances.

Reporting

The importance of prompt, accurate, and complete reports cannot be overemphasized.

SITE SELECTION

Select the most favorable trace for the route to follow. Future problems can be avoided by careful reconnaissance and wise consideration of future tactical, strategic, and post-hostilities needs. A project that is not well laid out may not meet the requirements for construction ease and efficiency, maintainability, usability, capacity, and convenience.

Wherever possible, use existing facilities. In most areas, an extensive road network already exists. With expansion and rehabilitation of the roadway and preparation of adequate surfaces, this network can carry required traffic loads.

Where new construction must be undertaken, the roadbed should be aligned to take advantage of the most favorable surface and subsurface terrain. An alignment over soil with good properties meets the design standards for strength and stability and minimizes the need to remove undesirable materials.

Drainage

Drainage patterns are also important in site selection. When the tactical situation permits, roads should be located on ridgelines. Thus, natural drainage features minimize the need for costly and time-consuming construction of drainage structures. Whenever possible, avoid subsurface water. If it is impossible to avoid road construction in saturated terrain, water tables must be lowered during construction. Steps must also be taken to minimize water's adverse effect on the strength of the supporting subgrade and base course.

Earthmoving

Earthmoving operations are the largest single work item on any project involving the construction of LOCs. Any step that can be taken to avoid excessive earthwork will increase job efficiency. Since all roads are a series of grades that seldom appear in nature, it is inevitable that some earthwork must be done. However, the amount to be done should be minimized by properly locating the route.

The engineer should take advantage of all prevailing grades that fall within the required specifications. Avoid excessive grades. Bypass steep hills whenever possible. If the route must negotiate excessively steep hills, it should run along the side of the hill. This may result in a longer route, but will prove to be more efficient in terms of earthwork and trafficability. Following contour lines on hillsides or ridgelines also avoids excessive grades and drainage construction.

It is important to make a careful analysis of the geology and ground cover within the proposed area of construction. Avoid wooded areas, extremely rocky soils, or undesirable humus, unnecessary clearing, and earthwork.

If possible, balance all necessary earthwork. When there is need for both cutting and filling at various points along a project, use excavated material to construct embankments. This reduces the need for earth handling. Plan balancing so that it fits the hauling capabilities of available equipment.

Even though it is desirable to balance earthwork throughout a project, long hauling distances may make it more practical to open a nearby borrow pit to obtain fill material or to establish spoil areas to dispose of excess soil. Obviously, balancing cannot be done where excavated material cannot be used for embankment.

Obstacles

Where possible, avoid obstacles such as rivers, ravines, and canals in order to minimize the need for bridge construction or for other similar structures. Such construction is time-consuming and calls for materials that may be in short supply. Make maximum use of existing structures to decrease total work requirements. Do not bridge an obstacle more than once. See Chapter 5 for further discussion of LOC bridging.

Curves and grades

Traffic flow over roads is far more efficient if curves and grades are held to a minimum. Even gentle curves significantly decrease traffic capacity if there are too many on a route. Therefore, lay out all routes with a minimum of curves by making the tangent lines as long as possible. The availability of long tangents is influenced by terrain. It is also limited by other principles of efficient location, such as minimizing earthwork, avoiding excessive grades, and obtaining desirable soil characteristics.

Materials

Road construction requires many different types of materials. These include aggregate for concrete and bituminous pavements, timber and steel for bridges, load-bearing soil for embankments, water for construction phases, and other supplies. If possible, roads should be located near construction materials. The basic construction usually strains the hauling capability of the unit, and readily available construction materials ease the strain.

SURVEYS

When a general route has been selected for new construction, a construction survey is initiated. In this survey, the team obtains data for all phases of construction activity. This survey includes reconnaissance, preliminary, final location, and construction layout surveys.

Reconnaissance survey

This survey provides a basis for selecting feasible sites or routes and furnishes information for use in later surveys. Use techniques discussed in the sections on reconnaissance and site selection. If a location cannot be selected on the basis of this survey, it will be chosen in the preliminary survey.

Preliminary survey

This survey is a detailed study of a location tentatively selected on the basis of reconnaissance, survey information, and recommendations. Surveyors run a traverse along a proposed route, record the topography, and plot results. Several such surveys may be needed if reconnaissance shows that more than one route is feasible. If the best available route is not already chosen, it should be selected now.

Final location survey

Conduct this survey if time permits. Establish permanent benchmarks for vertical control and well-marked points for horizontal control. This enables construction elements to accurately locate and match specific design locations with those on site.

Construction-layout survey

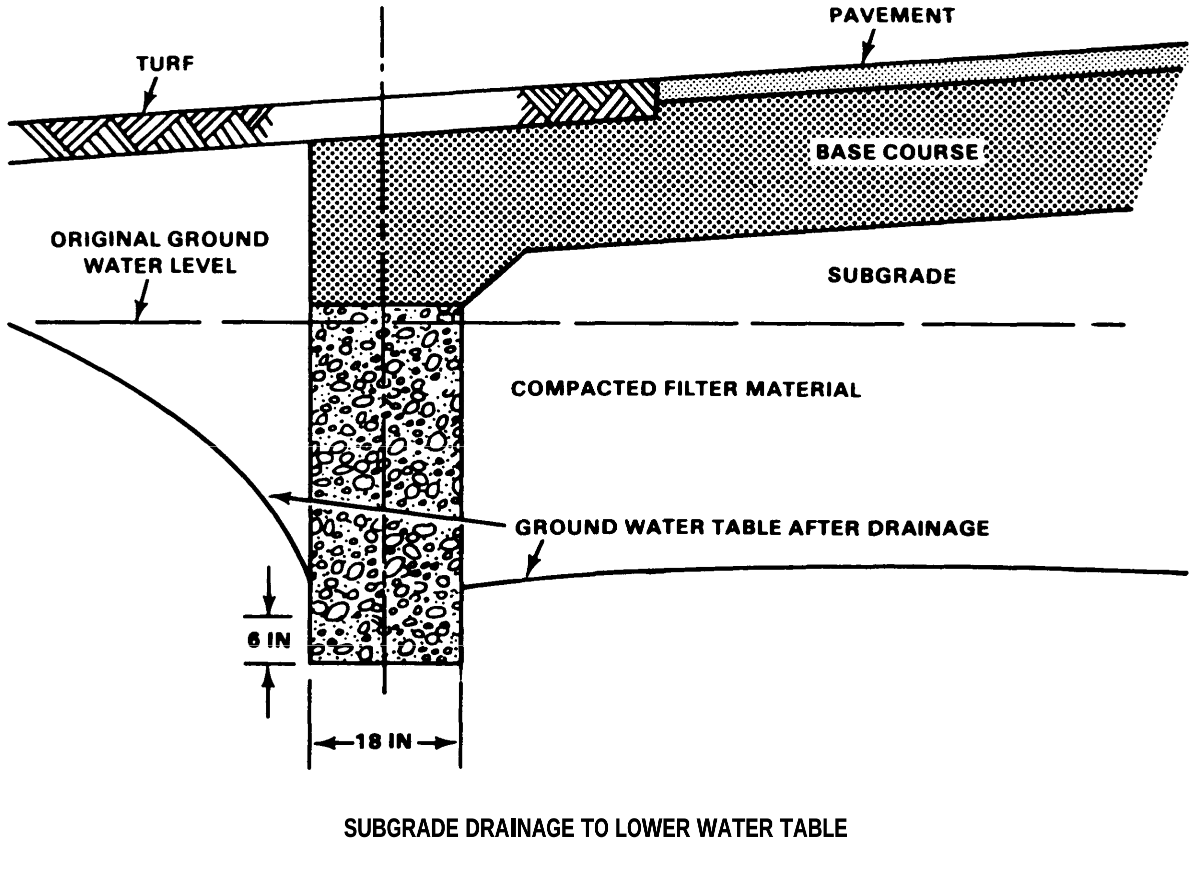
This is the final operation before construction begins. In this instrument survey, provide alignment, grades, and locations to guide construction operations. Make exact placement of the centerline; lay out curves; set all remaining stakes, such as slope, grade, shoulder; stake out necessary structures; lay out culvert sites; and perform other work required to enable construction to begin.

Carry on with this survey until construction is complete.

The main purpose of construction surveys is to ease and control construction. The number of surveys conducted and the extent to which they are carried out is largely governed by available time, construction standard, and by personnel and material assets. Roads in the combat zone may be constructed with minimal preplanning and construction control. However, extensive surveys may be conducted for a deliberate project in the COMMZ. The quality and efficiency of construction is strongly related to the number and extent of surveys and other preplanning activities.

DRAINAGE

Adequate drainage is essential during construction of a military road or airfield. Immediately provide adequate drainage for the site to ensure that all water that might interfere with construction operations is removed. Eliminate construction delays and subgrade failures due to pending of surface water by aggressive, timely development of a drainage system. Include temporary measures such as pumping. During clearing and grubbing operations, keep existing or natural watercourses clear, and fill and compact holes and depressions to grade. Rough crown and grade must be maintained to permit water from precipitation, sidehill seeps, and springs to move freely away from worksites by gravity flow. If water is permitted to pond, the subgrade becomes saturated and fails under load, earthmoving is impeded, and the need for equipment maintenance is increased.



SUBGRADE DRAINAGE TO LOWER WATER TABLE

In permanent peacetime construction, underground drains are often used because efficient use of space and safety practices do not permit large open ditches, particularly for disposal of collected runoff. In contrast, Theater of Operations design uses surface ditching almost exclusively because of limited pipe supplies and the absence of storm sewer systems to collect runoff.

Design the drainage system to remove surface water effectively from operating areas, to intercept and dispose of runoff from adjoining areas, to intercept and remove detrimental conditions of the selected design storm, and to minimize the effects of exceptionally adverse weather conditions.

Consider the proposed use of the road. If it is to be used only for a short time, such as 1 or 2 weeks, a detailed drainage design is not justifiable. However, if improvement or expansion is anticipated, design drainage so that future construction does not overload ditches, culverts, and other drainage facilities. Drainage problems are greater when all-weather use occurs than when only intermittent use occurs.

Consider the availability of engineer resources. Heavy equipment, such as dozers, graders, scrapers, and power shovels, is commonly used on drainage projects. But where unskilled labor and hand tools are readily available, much work can be done by hand.

Maintain the drainage system so that it functions efficiently. Inspect structures in both wet and dry weather. Give attention to obstructions, erosion, and failures in the system. A complete discussion of drainage design, construction, and maintenance is contained in Chapter 6 of TM 5-330.

CONSTRUCTION

When earthwork estimation, equipment scheduling, and necessary surveys are complete, the construction sequence can begin. Prepare the construction site by clearing, grubbing, and stripping. These operations are usually done with heavy engineer equipment. Hand or power felling equipment, explosives, and fire are used when applicable. The factors determining the methods to be used are the acreage to be cleared, the type and density of vegetation, the terrain's effect on equipment operation, the availability of equipment and personnel, and the time available for completion. For best results, use a combination of methods, choosing each method for the operation in which it is most effective.

Conduct cut and fill operations when clearing, grubbing, and stripping are finished. Cut and fill operations are the biggest part of the earthwork in road construction. The goal of cut and fill work is to bring the route elevation to design specifications. Throughout the fill operation, compact the soil in layers (lifts).

Achieve compaction with self-propelled or towed rollers. The end product is a structure that minimizes settlement, increases shearing resistance, reduces seepage, and minimizes volume change. The advantages that accompany soil compaction make this process standard procedure for constructing embankments, subgrades, and bases for road and airfield pavements.

Cut and fill and compaction efforts are intended to achieve the final grade. This alignment takes into consideration superelevation along curves to ensure load stability, and falls within the grade specifications required for the military road. When final grade is achieved, cut ditching to control drainage runoff and crown the road along its centerline. The road is now ready for surfacing.

PAVING

Decision makers consider paving a road in the Theater of Operations by taking account of the urgency of its completion, the tactical situation, the expected traffic, the soil bearing characteristics, the climate, and the availability of materials and equipment. Pavements, including the surface and underlying courses, are divided into two broad types—rigid and flexible. The wearing surface of rigid pavement is made of portland cement concrete.

All other types of pavements and bases are classified as flexible. Flexible pavements are used almost exclusively in the Theater of Operations. They are adaptable to almost any situation and fall within the construction capabilities of normal engineer troop units. Rigid pavements are not usually suited to Theater of Operations construction requirements.

Because flexible pavements reflect distortion and displacement from the subgrade upward to the surface course, their design must be based on complete and thorough investigations of subgrade conditions, borrow areas, and sources of select materials, subbase, and base materials. Specific information on pavement design is contained in TM 5-330 and 5-337.

SOIL STABILIZATION

The goals of soil stabilization are strength improvement, dust control, and soil waterproofing. Strength improvement increases the load-carrying ability of the road. Dust control alleviates or eliminates dust generated by vehicle and aircraft operation. Soil waterproofing maintains the natural or constructed strength of a soil by preventing water from entering it. Stabilization is generally accomplished by either mechanical or chemical methods.

In mechanical stabilization, soils are blended, then compacted. In chemical stabilization, soil particles are bonded to form a more stable mass. Additives such as lime, bitumen, or portland cement are used.

Dust control and soil waterproofing can be carried out by applying treatment materials in a spray (soil penetrants), a mix (admix), or by laying aggregate, membrane, or mesh as a soil blanket. The agronomic method, using vegetation cover, is suited to stable situations, and is rarely useful in the Theater of Operations. Technical Manual 5-830-2 discusses these techniques in detail.